Draft AC(J) 25.301(b) – Hoofddorp Meeting

(Hoofddorp, 17/04/02)

1. PURPOSE

This Advisory Circular (AC/ACJ) sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of Part 25 of the Federal Aviation Regulations (FAR) / JAR-25 related to the validation, by flight load measurements, of the methods used for determination of flight load intensities and distributions, for transport category/large aeroplanes.

2. RELATED FAR SECTIONS/ JAR PARAGRAPHS

FAR / JAR 25.301(b) "Loads"
FAR / JAR 25.459 "Special Devices"
AC 25-22 "Certification of Transport Airplane Mechanical Systems"

3. BACKGROUND

(a) FAR/JAR-25 stipulates a number of load conditions, such as flight loads, ground loads, pressurisation loads, inertia loads and engine/APU loads. FAR/JAR 25.301 requires methods used to determine load intensities and distributions to be validated by flight load measurements unless the methods used for determining those loading conditions are shown to be reliable. Although this applies to all load conditions of FAR/JAR-25, the scope of this AC(J) is limited to flight loads.

(b) The sizing of the structure of the aircraft generally involves a number of steps and requires detailed knowledge of air loads, mass, stiffness, damping, flight control system characteristics, etc. Each of these steps and items may involve its own validation. The scope of this AC(J) however is limited to validation of methods used for determination of loads intensities and distributions by flight load measurements.

(c) By reference to validation of "methods", FAR/JAR 25.301(b) and this AC(J) are intended to convey a validation of the complete package of elements involved in the accurate representation of loads, including input data and analytical process. The aim is to demonstrate that the complete package delivers reliable or conservative calculated loads for scenarios relevant to FAR/JAR-25 flight loads requirements.

(d) Some measurements may complement (or sometimes even replace) the results from theoretical methods and models. Some flight loads development methods such as those used to develop buffeting loads have very little theoretical foundation, or are methods based directly on flight loads measurements extrapolated to represent limit conditions.

4. NEED FOR AND EXTENT OF FLIGHT LOAD MEASUREMENTS

4.1. *General*

(a) The need for and extent of the flight load measurements has to be discussed and agreed between the Administrator / Authority and Applicant on a case by case basis. Such an assessment should be based on:

(i) a comparison of the design features of the aeroplane under investigation with previously developed (by the Applicant) and approved aeroplanes. New or significantly different design features should be identified and assessed.

(ii) the Applicant's previous experience in validating load intensities and distributions derived from analytical methods and/or wind tunnel tests. This experience should have been accumulated on previously developed (by the Applicant) and approved types and models of aeroplanes. The validation should have been by a flight load measurement program that was conducted by the Applicant and found acceptable to the Administrator / Authority for showing compliance.

(iii) the sensitivity to parametric variation and continued applicability of the analytical methods and/or wind tunnel test data.

(b) Products requiring a new type certificate will in general require flight-test validation of flight loads methods unless the Applicant can demonstrate to the Administrator / Authority that this is unnecessary.

If the configuration under investigation is a similar configuration and size as a previously developed and approved design, the use of analytical methods, such as computational fluid dynamics validated on wind tunnel test results and supported by previous load validation flight test experience, may be sufficient to determine flight loads without further flight test validation.

(c) Applicants who are making a change to a Type Certificated airplane, but who do not have access to the Type certification flight loads substantiation for that airplane, will be required to develop flight loads analyses, as necessary, to substantiate the change.

In general, the loads analyses will require validation and may require flight test loads measurements, as specified in this AC(J).

(d) The Applicant is encouraged to submit supporting data or test plans for demonstrating the reliability of the flight loads methods early in the certification planning process.

4.2. *New or significantly different design features.* Examples of new or significantly different design features include, but are not limited to:

- Wing mounted versus fuselage mounted engines;
- Two versus three or more engines;
- Low versus high wing;
- Conventional versus T-tail empennage;
- First use of significant sweep;
- Significant expansion of flight envelope;
- Addition of winglets;
- Significant modification of control surface configuration;
- Significant differences in airfoil shape, size (span, area);
- Significant changes in high lift configurations;
- Significant changes in power plant installation/configuration;
- Large change in the size of the aeroplane.

4.3. *Other considerations*

(a) Notwithstanding the similarity of the aeroplane or previous load validation flight test experience of the Applicant, the local loads on the following elements are typically unreliably predicted and may require a measurement during flight tests:

- Loads on high lift devices;
- Hinge moment on control surfaces;
- Loads on the empennage due to buffeting;
- Loads on any unusual device.

(b) For non-deterministic loading conditions, such as stall buffet, the applicant should compile a sufficient number of applicable flight loads measurements to develop a reliable method to predict the appropriate design load.

5. FLIGHT LOAD MEASUREMENTS

5.1. *Measurements.* Flight load measurements (for example, through application of strain gages, pressure belts, accelerometers) may include:

- Pressures / air loads /net shear, bending and torque on primary aerodynamic surfaces;
- Flight mechanics parameters necessary to correlate the analytical model with flight test results;
- High lift devices loads and positions;
- Primary control surface hinge moments and positions;
- Unsymmetric loads on the empennage (due to roll/yaw manoeuvres and buffeting);
- Local strains or response measurements in cases where load calculations or measurements are indeterminate or unreliable.

5.2. *Variation of parameters.* The test points for the flight loads measurements should consider the variation of the main parameters affecting the loads under validation. Examples of these parameters include: load factor, speeds, altitude, c.g., weight, power settings (thrust, for wing mounted engines), fuel loading, speed brake settings, flap settings and gear conditions (up/down) within the design limits of the aeroplane. The range of variation of these parameters must be sufficient to allow the extrapolation to the design loads conditions. In general, the flight test conditions need not exceed approximately 80% of limit load.

5.3. *Conditions.* In the conduct of flight load measurements, conditions used to obtain flight loads may include:

- Pitch manoeuvres including wind-up turns, pull-ups and push-downs (e.g. for wing and horizontal stabiliser manoeuvring loads);
- Stall entry or buffet onset boundary conditions (e.g. for horizontal stabiliser buffet loads);
- Yaw manoeuvres including Rudder inputs and steady sideslips;
- Roll manoeuvres.

Some flight load conditions are difficult to validate by flight load measurements, simply because the required input (e.g. gust velocity) cannot be accurately controlled or generated. Therefore, these type of conditions need not be flight tested. Also, in general, failures, malfunctions or adverse conditions are not subject to flight tests for the purpose of flight loads validation.

5.4. *Load alleviation.* When credit has been taken for an active load alleviation function by a particular control system, the effectiveness of this function should be demonstrated as far as practicable by an appropriate flight test program.

6. RESULTS OF FLIGHT LOAD MEASUREMENTS

6.1. *Comparison / Correlation.* Flight loads are not directly measured, but are determined through correlation with measured strains, pressures or accelerations. The load intensities and distributions derived from flight testing should be compared with those obtained from analytical methods. The uncertainties in both the flight testing measurements and subsequent correlation should be carefully considered and compared with the inherent assumptions and capabilities of the process used in analytic derivation of flight loads. Since in most cases the flight test points are not the limit design load conditions, new analytical load cases need to be generated to match the actual flight test data points.

6.2. *Quality of measurements.* Factors which can affect the uncertainty of flight loads resulting from calibrated strain gages include the effects of temperature, structural non-linearities, establishment of flight/ground zero reference, and large local loads, such as those resulting from the propulsion system installation, landing gear, flap tracks or actuators. The static or dynamic nature of the loading can also affect both strain gage and pressure measurements.

6.3. *Quality of correlation.* A given correlation can provide a more or less reliable estimate of the actual loading condition depending on the "static" or "flexible dynamic" character of the loading action, or on the presence and level of large local loads. The quality of the achieved correlation depends also on the skills and experience of the Applicant in the choice of strain gage locations and conduct of the calibration test programme.

Useful guidance on the calibration and selection of strain-gage installations in aircraft structures for flight loads measurements can be found, but not exclusively, in the following references:

1. Skopinski, T.H., William S. Aiken, Jr., and Wilbur B. Huston, "Calibration of Strain-Gage Installations in Aircraft Structures for Measurement of Flight Loads", NACA Report 1178, 1954.

2. Sigurd A. Nelson II, "Strain Gage Selection in Loads Equations Using a Genetic Algorithm", NASA Contractor Report 4597 (NASA-13445), October 1994.

6.4. *Outcome of comparison / correlation.* Whatever the degree of correlation obtained, the Applicant is expected to be able to justify the elements of the correlation process, including the effects of extrapolation of the actual test conditions to the design load conditions.

If the correlation is poor, and especially if the analysis underpredicts the loads, then the Applicant should review and assess all of the components of the analysis, rather than applying blanket correction factors.

For example:
(a) If the level of discrepancy varies with the Mach number of the condition, then the Mach corrections need to be evaluated and amended.
(b) If conditions with speed brakes extended show poorer correlation than clean wing, then the speed brake aerodynamic derivatives and/or spanwise distribution need to be evaluated and amended.

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